

3D printing optical preforms and fibres

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Abstract: A review of work towards the additive manufacture of optical fibres is presented.

The entry of additive manufacture, or 3D printing, into optical fibre fabrication will disrupt the sector. Essentially it is offering an alternative technique to chemical vapour deposition (CVD) approaches that currently dominate fibre fabrication. Why would this be the case? If one examines one of the key features of optical fibre innovation in recent decades it has not been fibre fabrication per se but the rise of structured optical fibres because of the potency of distributing geometric topologies to control and manipulate light, where it be with multiple cores or with transverse profiling of dispersion or other. This simply reflects the physical limitation involved with CVD approaches – a spinning lathe means a centralized core and point of deposition, clearly not amenable for off-centre topologies or configurations. Except for direct drilling of preforms, the precursor stage to drawing optical fibre, every other approach has relied on extracting tubes, rods or capillaries and through mostly manual and tedious assembly combined to produce the preforms needed. This has been fine for geometrically circular structures that can be readily stacked but has not been easy for more complex structures – where drilling has come in. But drilling is limited in resolution and capability – thus one of us first identified additive manufacture as the solution to this challenge.

The first experiments started simply enough, demonstrating polymer preform fabrication using fused deposition modelling (FFDM) where polymer feed was melted and drawn into a preform shape before subsequent drawing into fibre [1,2], a fruitful exercise that demonstrated the approach as an alternative to existing polymer preparation methods and in doing so greatly increased material scope as well as arbitrary topologies. The immediate benefit for short distance communications and sensing were clear and it was time to tackle silica. However, here we are talking a substantive thermal jump – melting silica requires temperature approaching 1900 °C and clearly FDM methods were restricted by materials and viscous flow to very poor resolution printing of the type [3]. Instead, we recognised a photopolymer approach was necessary and a literature search revealed some glass work had indeed be printed this way [4]. However, it was very small scale no more than a few mm and we needed to improve and extend this – that meant overcoming errors in the project-based methods and finding an optimal balance between viscous flow under the extraction plane. The work from Germany used an award winning Australian direct light project (DLP) printer manufactured in Sydney by a former colleague of ours (J. Elsey, Asiga.com). Using this printer and optimising processing conditions we were able to accelerate extension of the photo-based method to tens of cm allowing us to produce practical preforms that can be drawn on our existing draw towers. Using this approach, the first silica based optical fibres were produced from additively manufactured preforms [5].

The major driver behind this research has been the ultimate production of any optical fibres by anyone: i.e. desktop fibre fabrication for the consumer. It arose from frustrations at extraordinarily high costs for implementing a fibre-to-the-home internet in Australia – it is too high and too difficult to get support and ultimately the consumer has to pay. If that is the case, then why not produce ones own fibres and connect up eh final fibre to the curb with home made optical fibre? Even if losses are not going to meet international transmission, over short distances this will not matter. Analysing the drawing optical fibres, why do they require such tall draw towers? These days with precision micro thermal elements within 3D printers it should be possible to go beyond preforms to directly produce optical fibre. This was tested by successfully drawing 30 um precision capillaries by hand from a very low-cost budget printer [6] – this it is clear that with a modified thermal head once can draw fibre directly from 3D filament today at home as one chooses. Others have since demonstrated structured fibre this way after reading our work [7].

The next big question is whether silica can be drawn on a desktop printer? A simple analysis suggests there is no physical reason providing the micro oven, drawing tension and speed are appropriate why it cannot be drawn on a customized high temperature oven on a desktop – the technology exists it is imply that we have not considered this before. We are looking to work with other parties that can produce a suitable and low-cost consumer ultra-high printer head for this work but something already developed by MIT can do this today. Whilst such high temperature heaters may be challenging and may very well require regular maintenance to ensure appropriate

OHS standards, they are in principle simple and potentially lower cost than other methods which are also being explored.

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